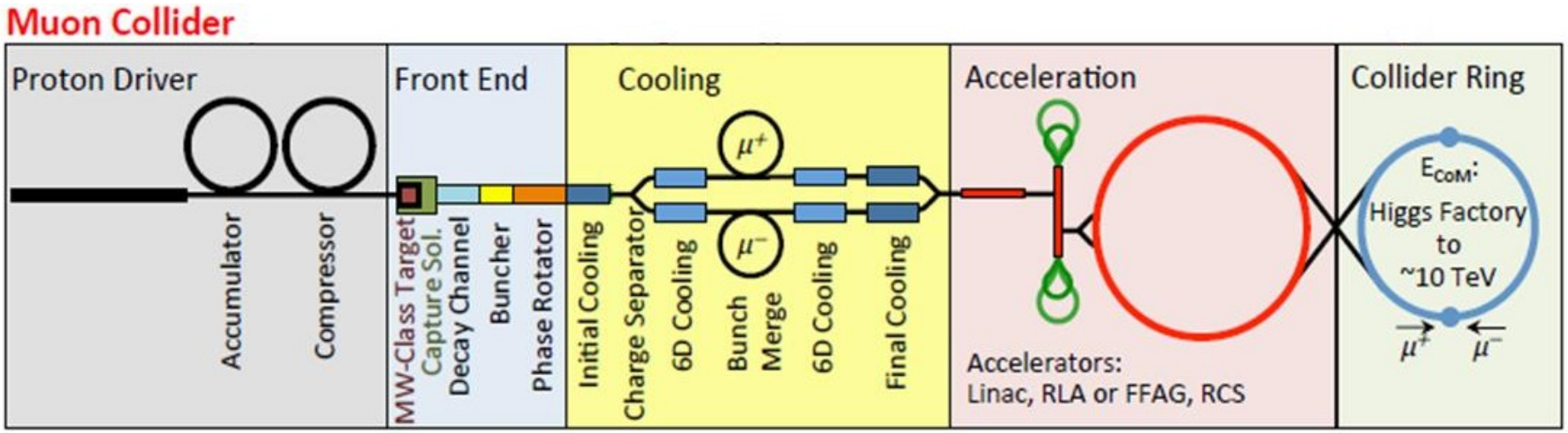
Capture and Cooling Working Group Summary and Progress

C. T. Rogers
ISIS
Rutherford Appleton Laboratory

Muon Collider Facility



- Reminder – muon collider facility (proton-based)
  - Protons on target in high-field solenoid → pions, muons et al.
  - **Clean up beam impurities**
  - **Capture muons longitudinally**
  - **Transverse and longitudinal cooling**
  - Acceleration
  - Collider ring

} Capture and cooling Working group

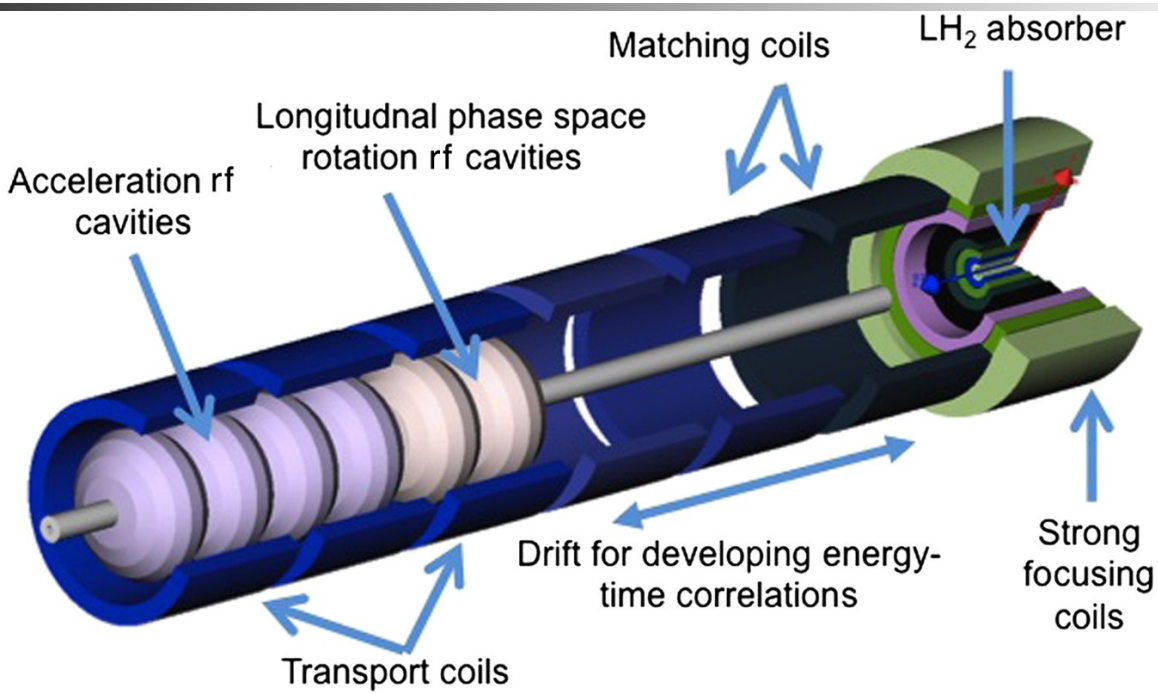
Job List

- Get hold of lattices
  - Check they run and we can reproduce results
  - Establish where lattices are missing or incomplete
- Develop and maintain hardware requirements
  - Liaise with magnet and RF teams as required
- Work on improving performance and developing new concepts
  - Especially final cooling
- Identify technical issues/risks
- Work on mitigating risk
  - MICE Results
  - Demonstrator design work
- Cost optimisation
  - E.g. rings
- **Please let me know if you would like to help!**

This talk

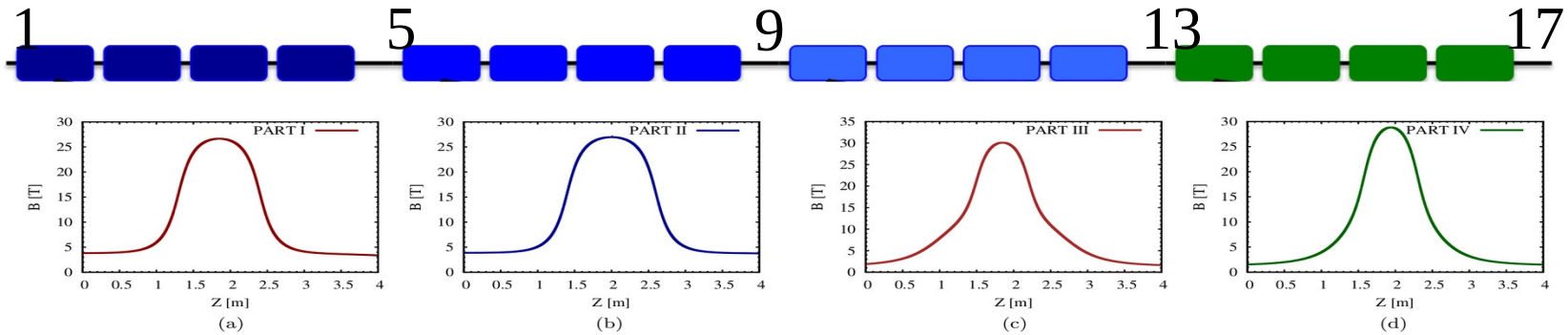
- Update on final cooling simulations (Bernd, Elena)
- Update on demonstrator simulations
- Comment on MICE analyses

Final cooling (H. Sayed et al)



- Challenge is to get very tight focussing to get low emittance
- Go to higher fields and lower momenta
  - Causes more longitudinal emittance growth
  - Chromatic aberrations introduce challenges
    - Elaborate phase rotation required to keep energy spread small
    - Move to low RF frequency to manage time spread

Final cooling (H. Sayed et al)

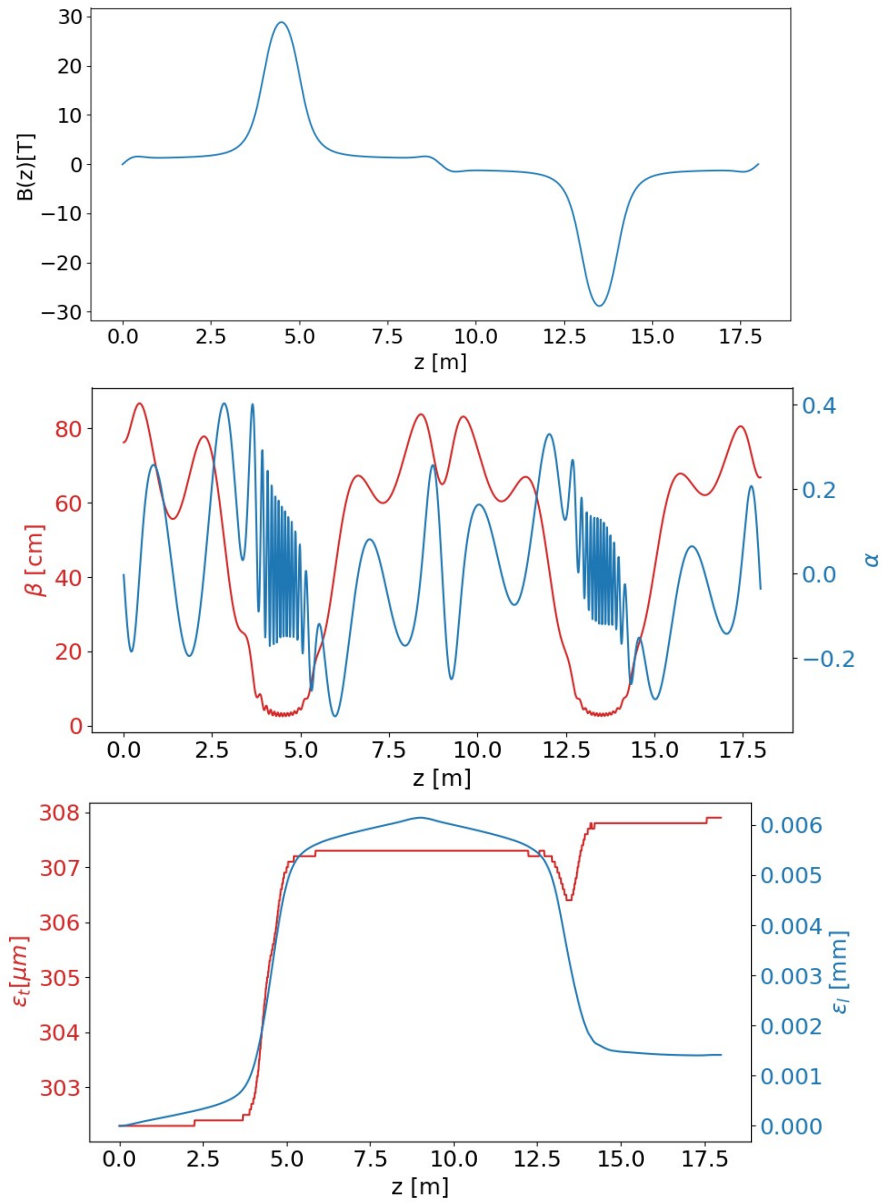


Stage	1	5	9	13	17
β [mm]	33	30	26	21	18
ε [mm]	0.3	0.2	0.15	0.11	0.06
p [MeV/c]	135	122	106	88	70
σ(x) [mm]	7.75	5.20	3.89	2.77	1.63
3σ(x) [mm]	23.24	15.59	11.66	8.32	4.89

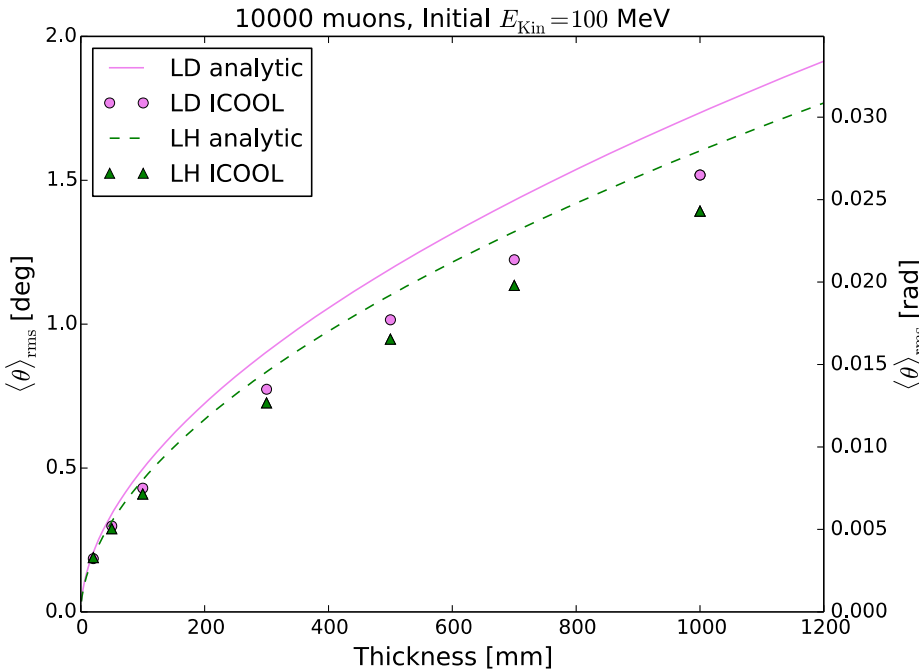
- Now attempting to recreate and extend H. Sayed's lattice
  - Transverse optics is quite fiddly – very low β
  - Getting a handle on tracking through single cells…

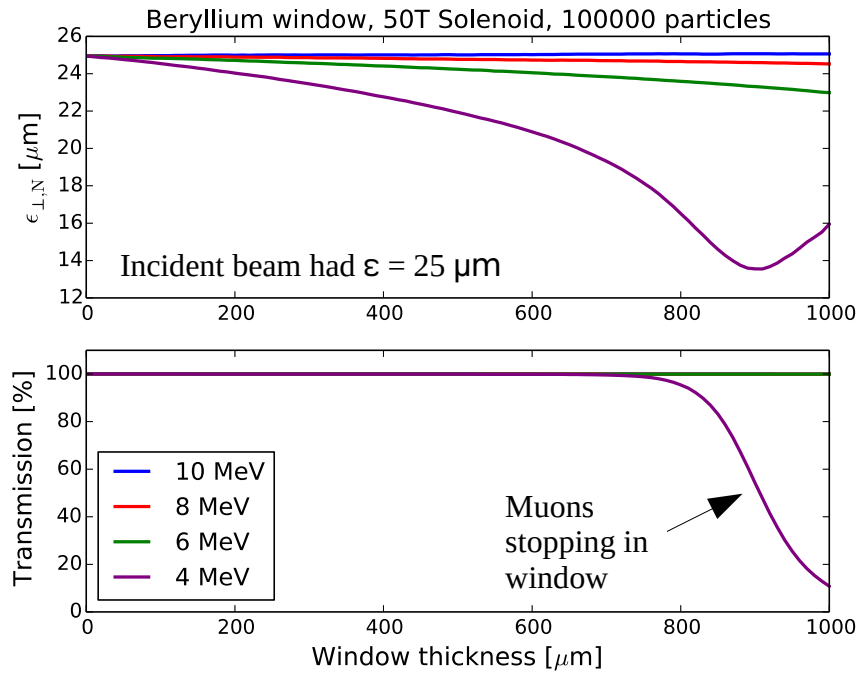
Beam matching (E. Fol)

- Build a periodic solenoid lattice in ICOOL
- Uses “realistic” model for solenoids
  - Based on sum over infinitely thin cylindrical current sheets
  - Extensive fringe fields
  - Include adjacent cell to get periodic solenoid field
- Developed matching algorithm
  - Produces okay results
  - Still some mismatch at the beginning (z=0)
    - Maybe need more than one adjacent cell(!)
  - Some emittance growth
    - With initial $\varepsilon_L = 0$



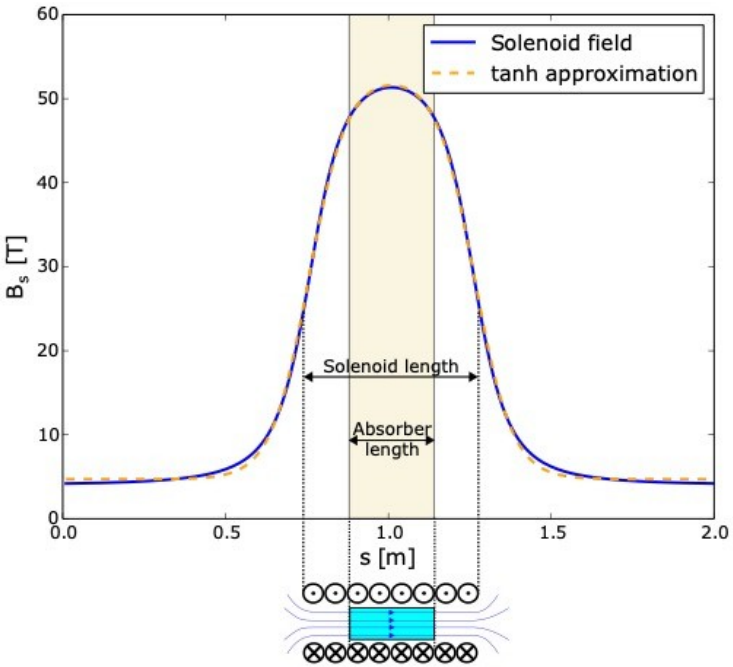
Absorber Simulation (B. Stechauner)

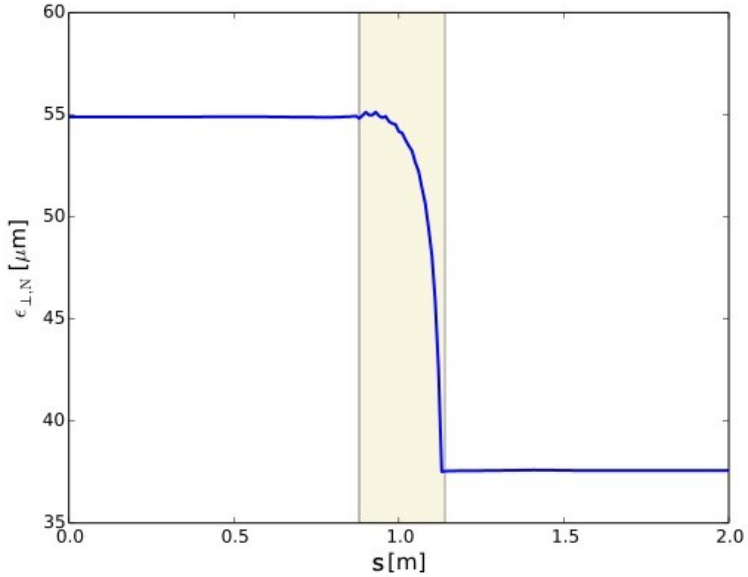




- Single absorber simulation to cross-check ICOOL (Fano)
  - ICOOL tends to under estimate scattering compared to PDG
  - This is consistent with e.g. Moliere and MICE measurements in LiH
- Heating effect in windows assuming β for 50 T
  - β = 6 mm for 10 MeV
  - β = 4 mm for 4 MeV

Transverse cooling (B. Stechauner)

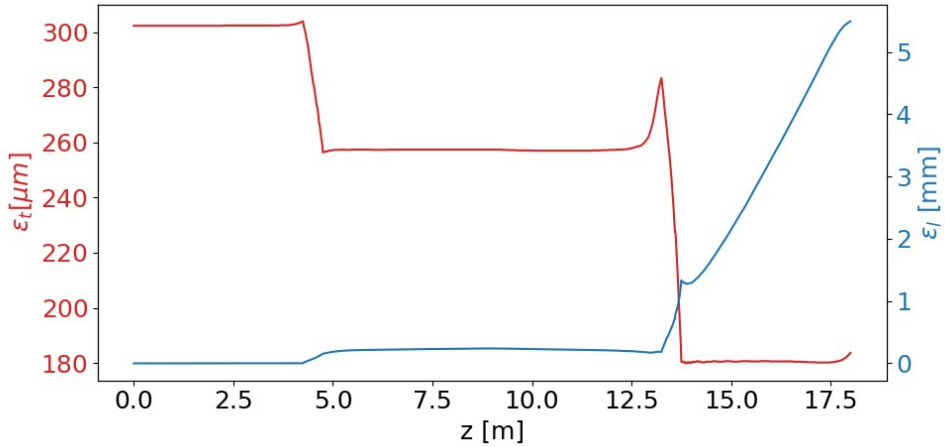


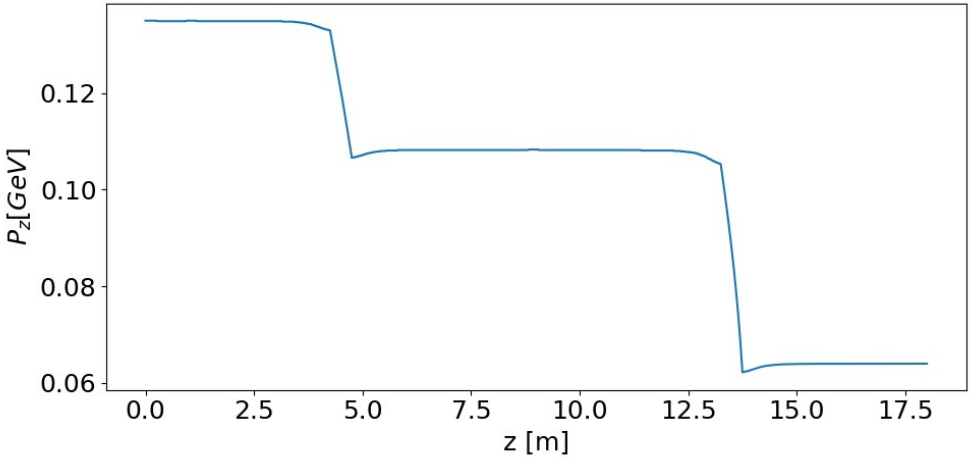


- Emittance change looks promising
  - Need to extend to lower emittances
  - Add in longitudinal phase space...

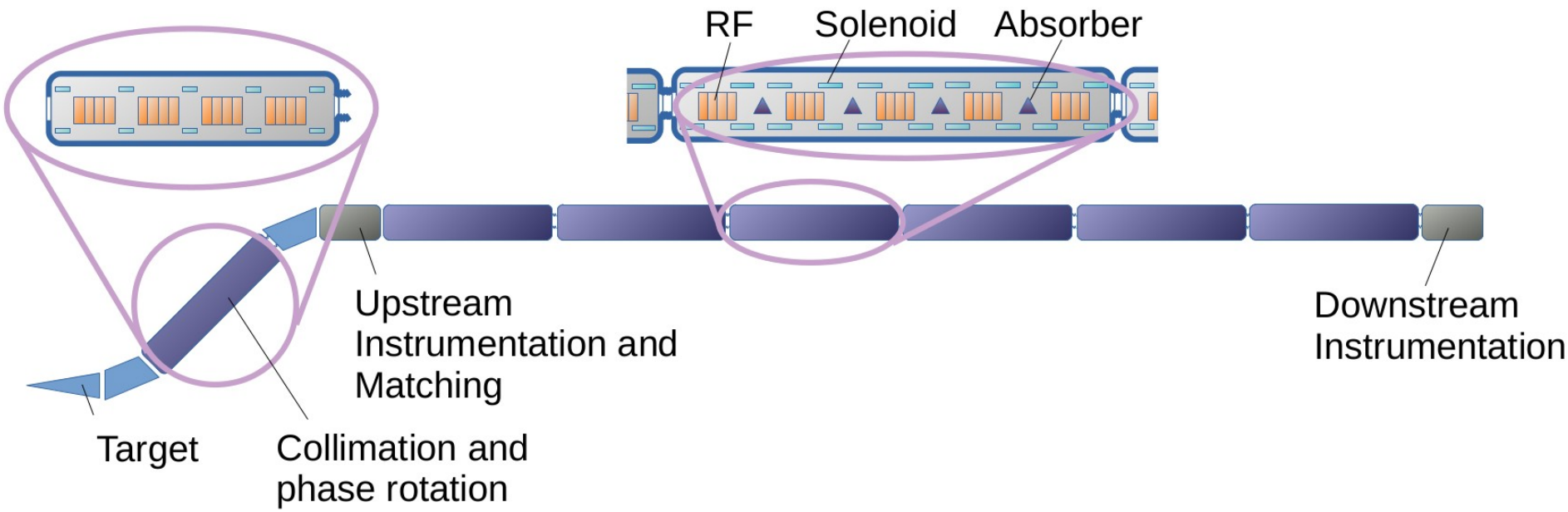
Lattice cooling (E. Fol)

- Started looking at chaining cells
  - No RF
- Energy spread already looking interesting
  - More cells → worse



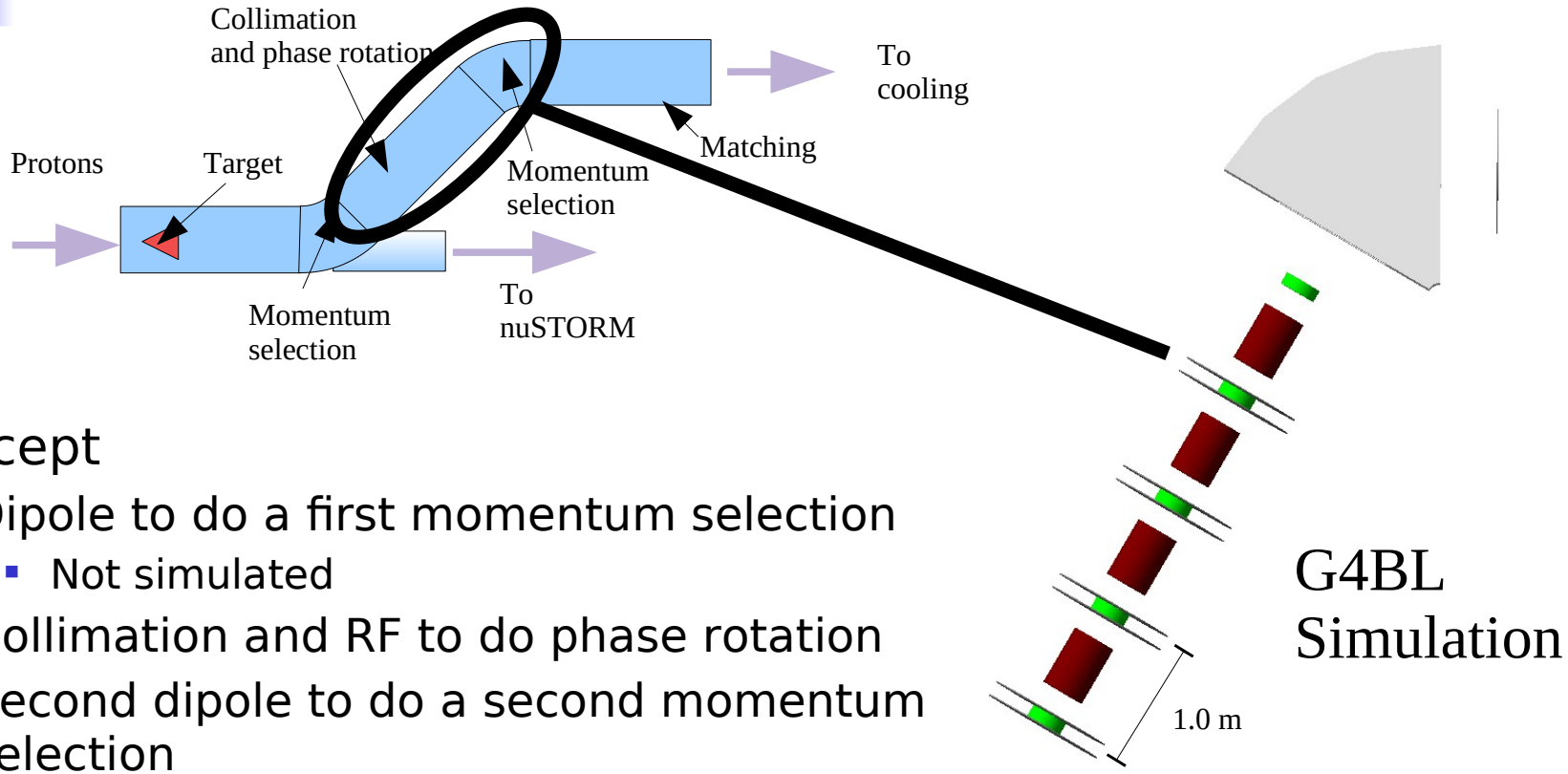


Demonstrator Physics Layout



- Working through layout for demonstrator
- Basic lattice for the cooling section shown previously
- Would like to understand collimation system
  - What is the muon rate?
  - What target is required?
  - What diagnostics can be used?
  - Can the demonstrator be compatible with e.g. nuSTORM?

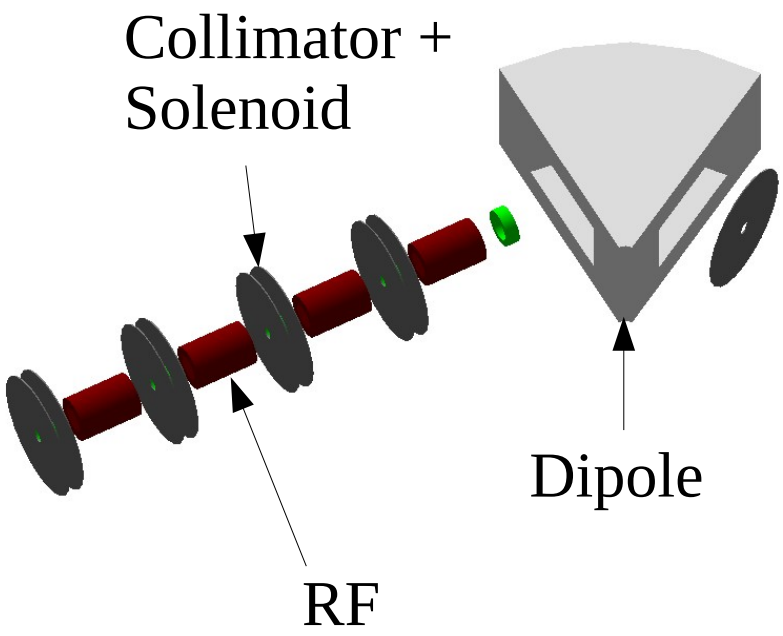
Collimation System



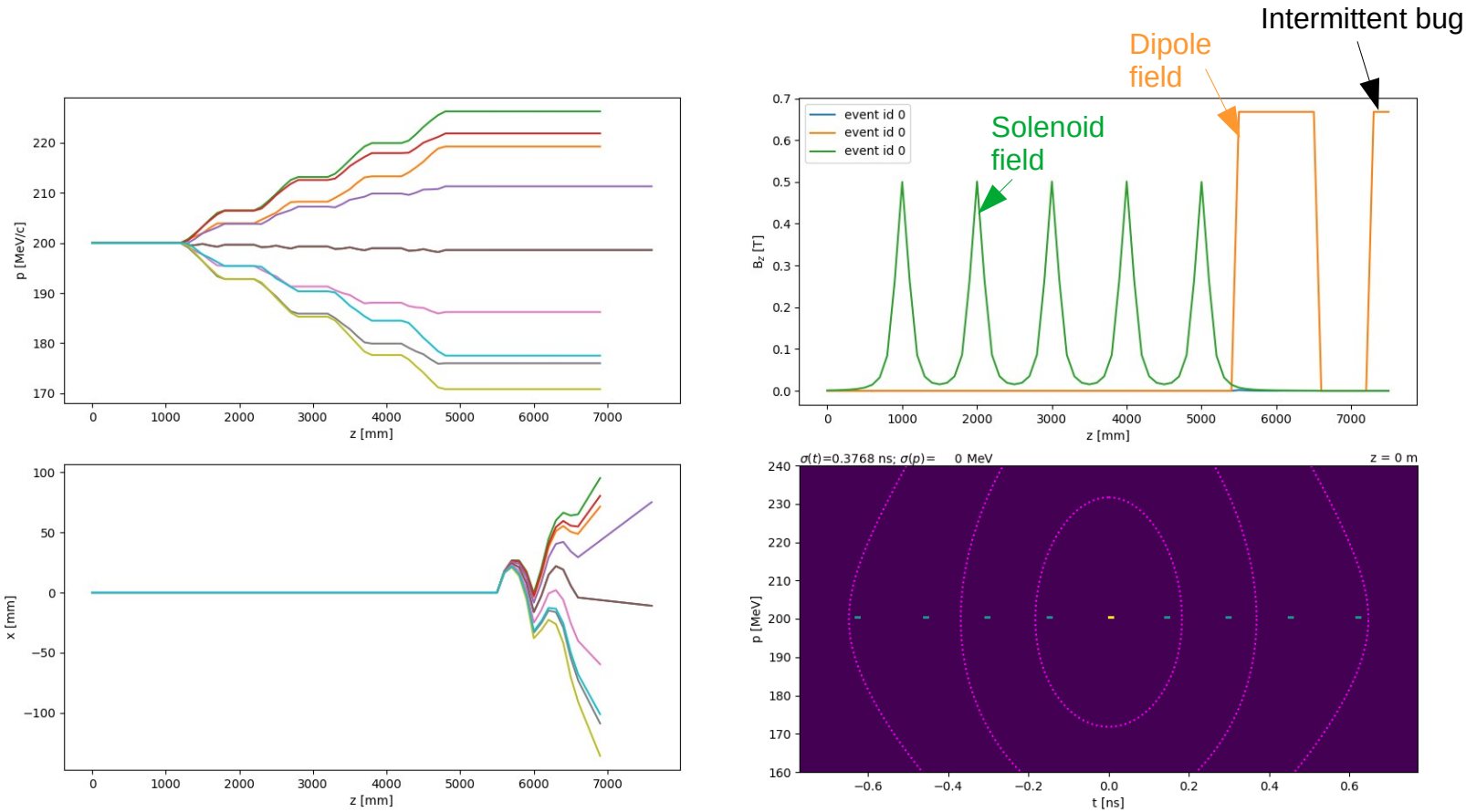
- Concept
  - Dipole to do a first momentum selection
    - Not simulated
  - Collimation and RF to do phase rotation
  - Second dipole to do a second momentum selection

Lattice

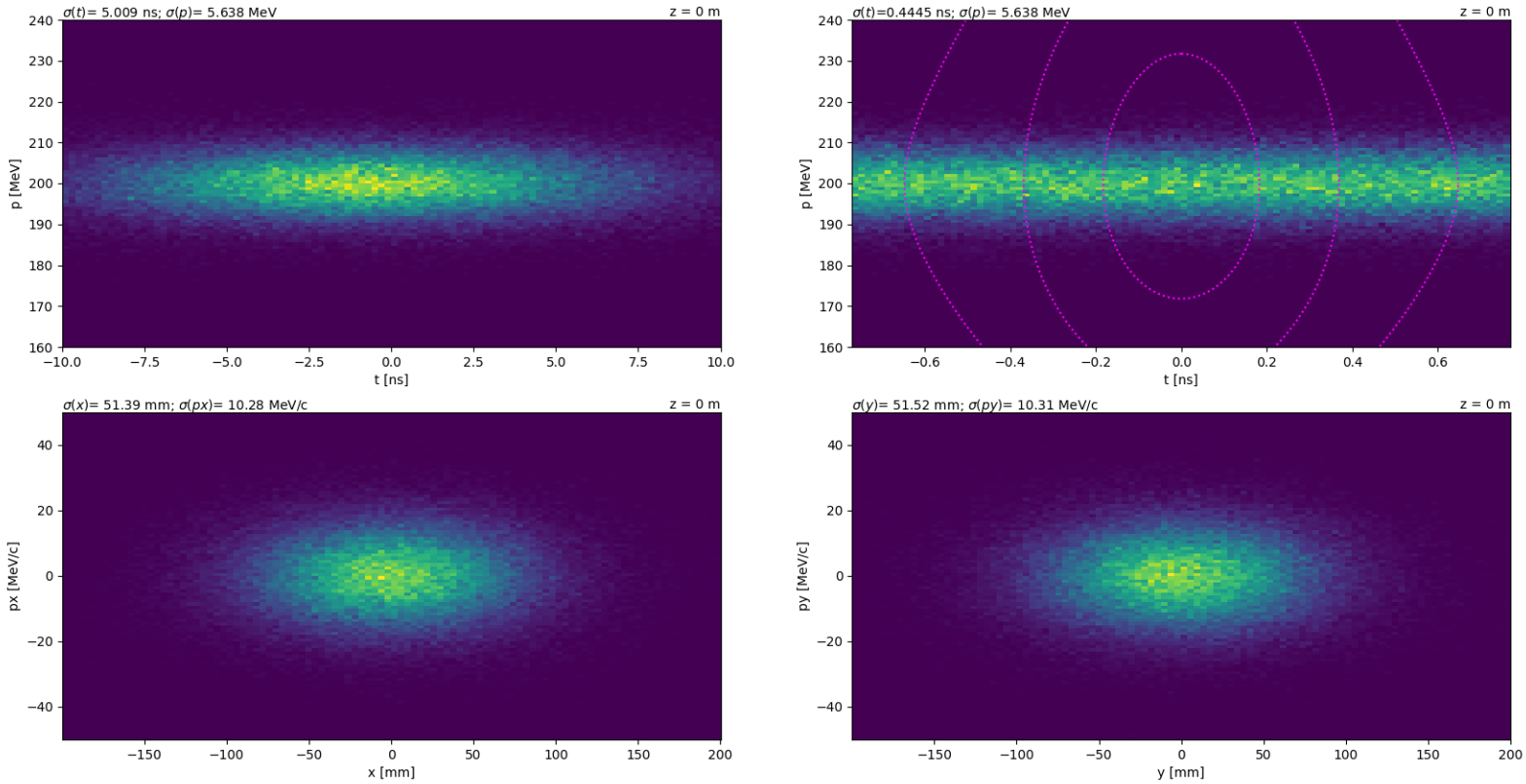
- 1 m cell length
  - 0.5 T solenoids, 50 mm radius pipe
  - 0.125 m, 650 MHz RF cavities
  - 4 cavities per cell (and 4 cells)
  - 15 MV/m peak gradient
  - Running in “bunching” mode
- 0.7 T dipole
  - 45 degree bend
- All apertures are perfect collimators
- No electrons
- No pions



Lattice

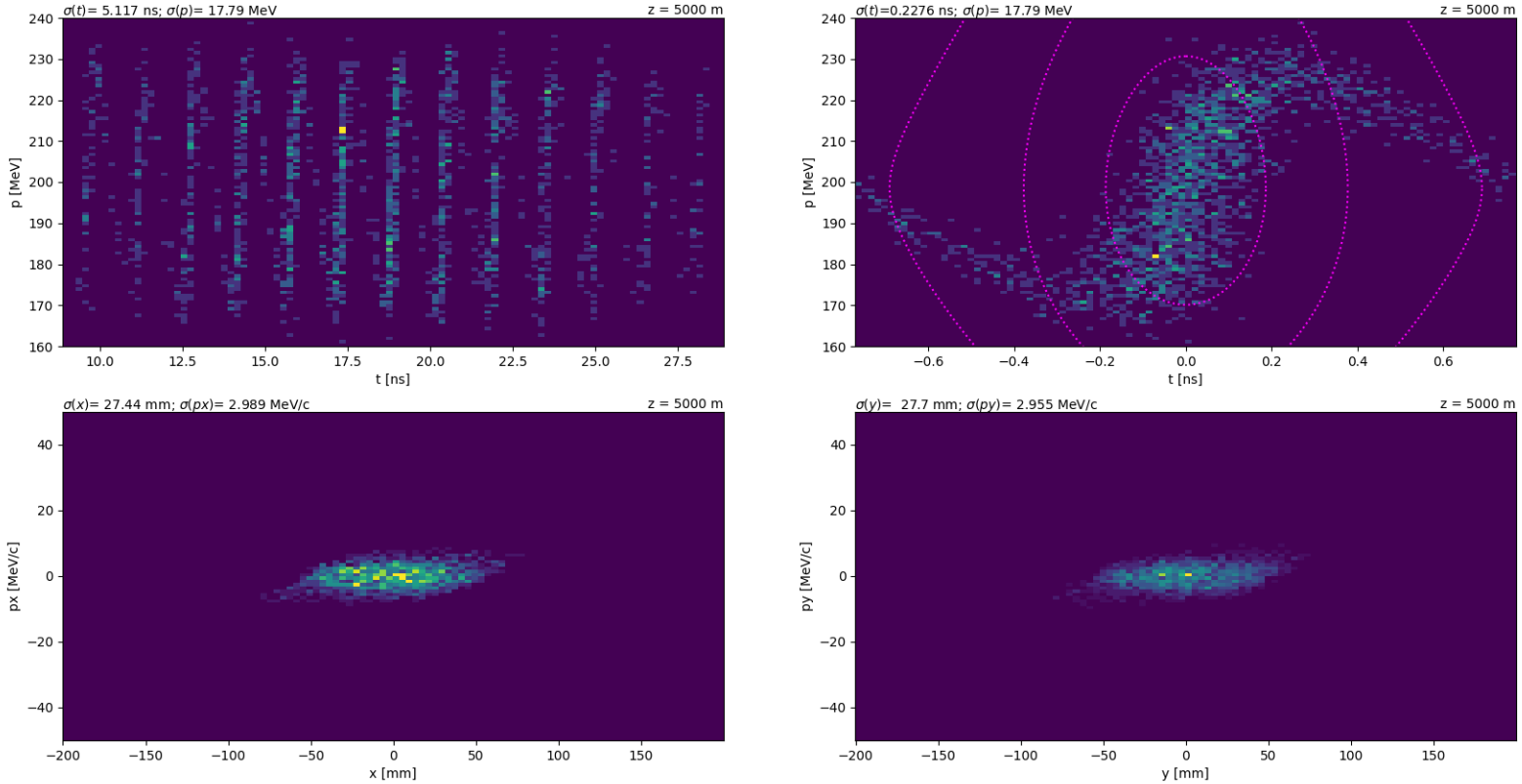

Intermittent bug
Dipole field
Solenoid field
event id 0
event id 0
event id 0
p [MeV/c]
z [mm]
B_z [T]
z [mm]
x [mm]
z [mm]
σ(t)=0.3768 ns; σ(p)= 0 MeV
z = 0 m
p [MeV]
t [ns]

Beam distribution at start

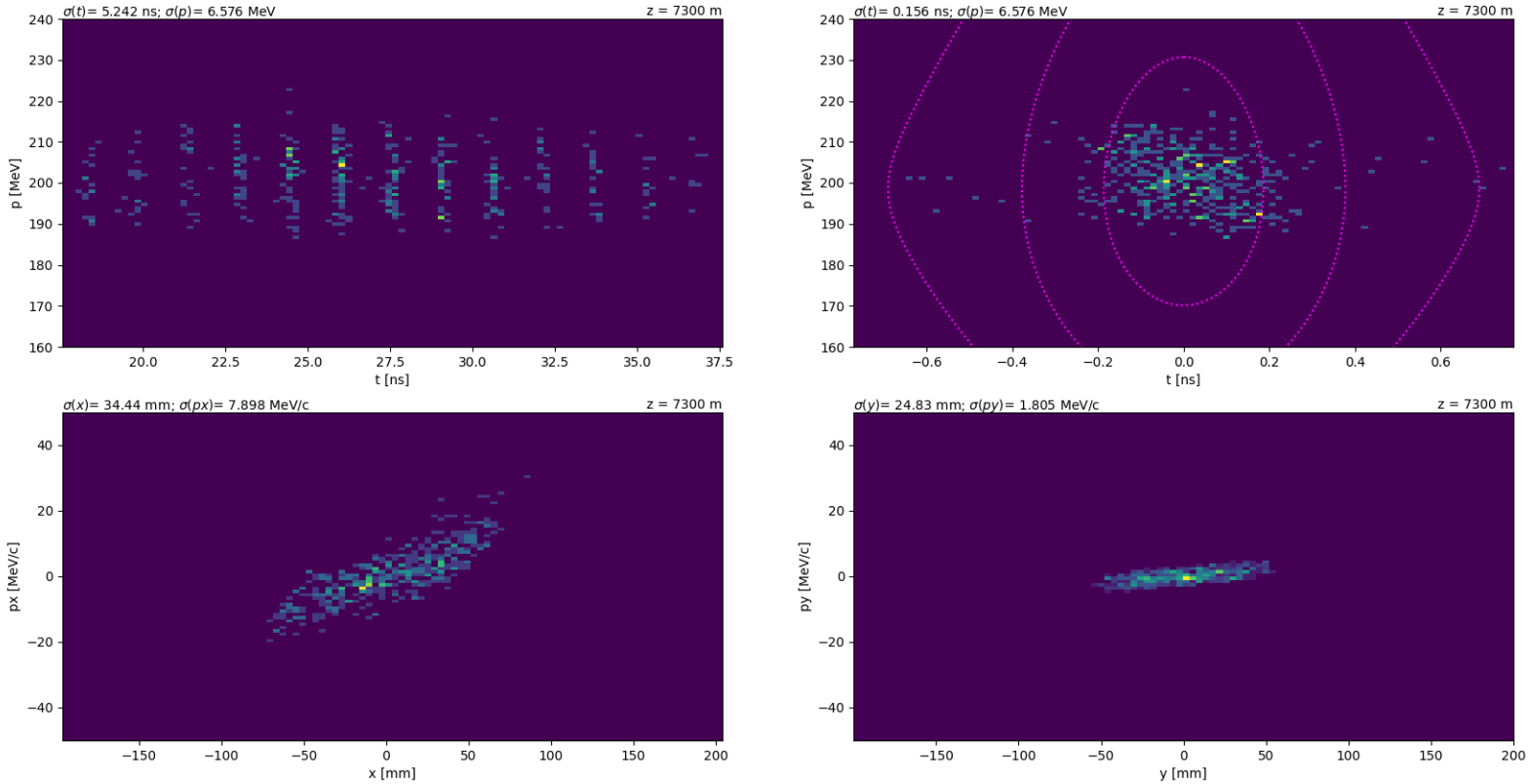


- Beam is supposed to fill the aperture **except** in momentum
  - Assumes not much collimation before first dipole (TBC)
- Momentum spread 10 MeV/c RMS
- Time spread long compared to RF frequency

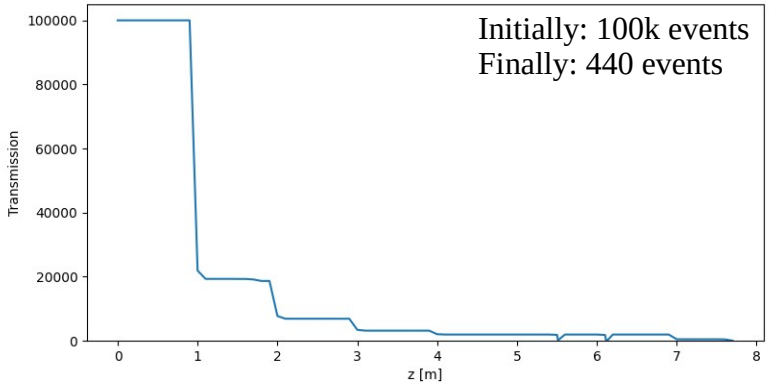
Beam distribution after RF

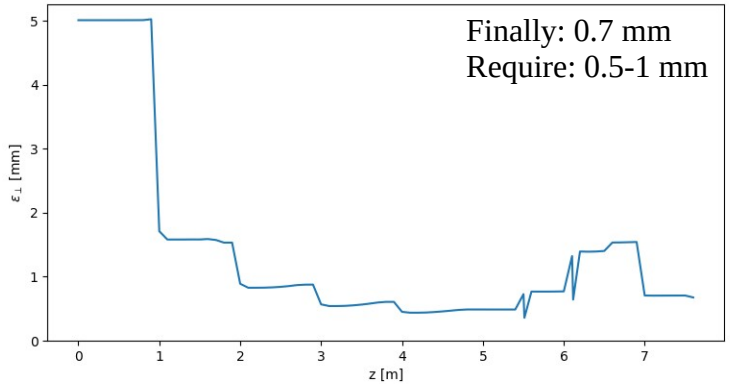


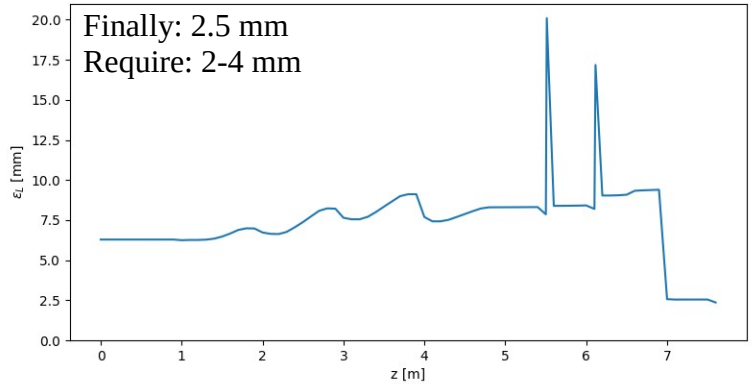
Beam distribution after dipole

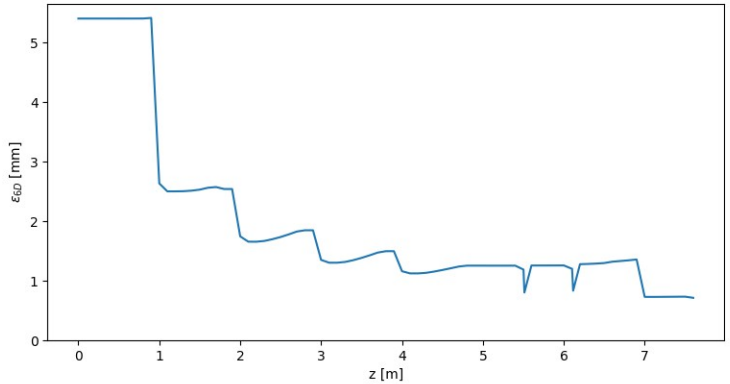


Beam evolution



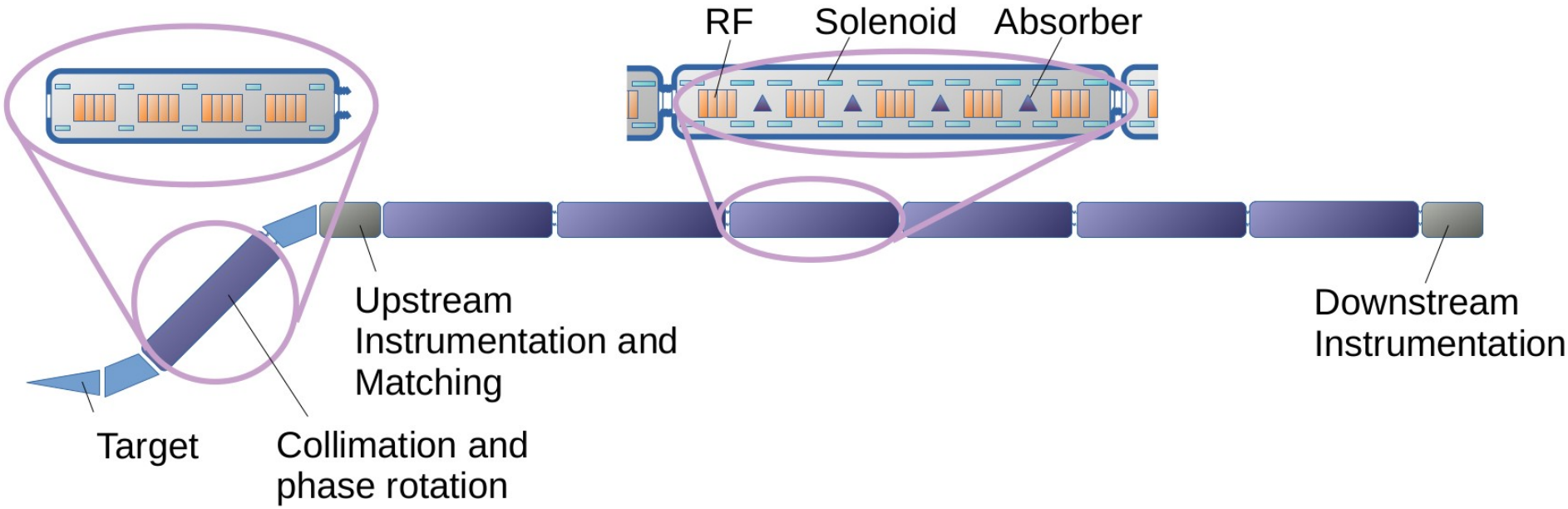






Comments

- Comments
  - Looks like the time selection is not too bad
  - Relies on quite tight energy selection in first dipole – not simulated
    - Alternatively, need taller RF bucket (more voltage)
    - (More voltage might be preferred by RF system)
  - Quadrupole focussing worth investigating
    - Generate asymmetric beams
  - What about pions/beam impurities?



Comment on MICE Progress

- Latest round of MICE analyses in progress
  - Several new datasets have been analysed
    - Solenoid mode (Tom Lord)
    - New analysis of flip mode (Paul Jurj)
    - Wedge absorber (Craig Brown)
    - LH2 scattering data (Gavriil Chatzitheodoridis)
  - Focus is on understanding/reducing systematic uncertainty
  - Student theses are in progress
  - Hope to bring to publication as students graduate

Conclusions

- Final cooling simulations are further developed
  - Building decent understanding of transverse lattice behaviour
  - Seek to add in longitudinal/RF simulations
- Demonstrator simulation developed
  - Snowmass submission has been invited on nuSTORM by mid-January
  - Would like to understand to what extent demonstrator is compatible
- MICE analysis is in progress
  - Study of systematic uncertainty